

What is claimed is:

1. An optical element of an optical pickup device for reproducing and/or recording information for a first optical information recording medium having a protect substrate thickness t_1 by using a light beam having a first wavelength λ_1 emitted from a first light source, and for reproducing and/or recording information for a second optical information recording medium having a protect substrate thickness t_2 ($t_2 \geq t_1$) by using a light beam having a second wavelength λ_2 ($\lambda_2 > \lambda_1$) emitted from a second light source, comprising:

a diffractive structure having a plurality of diffracting ring-shaped zones arranged around an optical axis on at least one optical surface; and

an optical path difference giving structure arranged on an optical surface of at least one of the plurality of diffracting ring-shaped zones, for giving a prescribed optical path difference to a prescribed light beam passing through the diffracting ring-shaped zone,

wherein the optical surface of the diffractive structure is a structure having a diffracting function for setting L-th ($L \neq 0$) order diffracted light of the light beam having the first wavelength λ_1 to a maximum diffraction efficiency and for setting M-th ($M \neq 0$) order diffracted light of the light beam having the second wavelength λ_2 to a maximum diffraction efficiency in case

of an assumption of no existence of the optical path difference giving structure.

2. The optical element of claim 1; wherein as compared with the assumption of no existence of the optical path difference giving structure, the optical path difference giving structure lowers an absolute value of an optical phase difference between the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 by changing a phase of at least one of the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 , the L-th order diffracted light and the M-th order diffracted light being caused by the structure having the diffracting function.

3. The optical element of claim 1; wherein as compared with the assumption of no existence of the optical path difference giving structure, the optical path difference giving structure lowers an absolute value of an optical phase difference between the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 by substantially giving no change

of a phase of one of the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 and by giving a phase difference to the other of the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light having the light beam having the second wavelength λ_2 , the L-th order diffracted light and the M-th order diffracted light being caused by the structure having the diffracting function.

4. The optical element of claim 1; wherein as compared with the assumption of no optical path difference giving structure, the optical path difference giving structure lowers an absolute value of an optical phase difference between the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 by giving a phase difference to both the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 , the L-th order diffracted light and the M-th order diffracted light being caused by the structure having the diffracting function.

5. The optical element of claim 1; wherein as compared with the assumption of no optical path difference giving structure, the optical path difference giving structure lowers an absolute value of an optical phase difference between the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 by giving an optical path difference approximately equal to an integral multiple having the first wavelength λ_1 to the L-th order diffracted light of the light beam having the first wavelength λ_1 to substantially give no change of a phase difference generated by the diffractive structure and by giving an optical path difference not equal to an integral multiple having the second wavelength λ_2 to the M-th order diffracted light of the light beam having the second wavelength λ_2 .

6. The optical element of claim 1; wherein the optical path difference giving structure sets the absolute value of the optical phase difference to a value lower than 0.6π radians.

7. The optical element of claim 1; wherein the structure having the diffracting function has a discontinuous surface formed in a serrate shape, and

the optical path difference giving structure has a discontinuous surface formed in a stepped shape along a direction of the optical axis.

8. The optical element of claim 1; wherein the structure having the diffracting function has a discontinuous surface formed in a stepped shape along a direction of the optical axis, and

the optical path difference giving structure has a discontinuous surface formed in a stepped shape along the direction of the optical axis.

9. The optical element of claim 1; wherein the optical surface comprises a central region arranged around the optical axis and formed in an approximately circular shape, and a peripheral region arranged at a periphery of the central region,

the structure having the diffracting function and the optical path difference giving structure are provided in the central region, and

the diffractive structure formed in a serrate shape is provided in the peripheral region.

10. The optical element of claim 1; wherein the optical surface comprises a central region arranged around the optical axis and formed in an approximately circular

shape, and a peripheral region arranged at a periphery of the central region,

the structure having the diffracting function and the optical path difference giving structure are provided in the central region, and

the optical path difference giving structure is provided in the peripheral region.

11. The optical element of claim 1; wherein the optical surface comprises a central region arranged around the optical axis and formed in an approximately circular shape, and a peripheral region arranged at a periphery of the central region,

the structure having the diffracting function and the optical path difference giving structure are provided in the central region, and

a refractive structure for refracting a light beam is arranged in the peripheral region.

12. The optical element of claim 1; wherein $L = M$ is satisfied.

13. The optical element of claim 1; wherein $L = M = 1$ is satisfied.

14. The optical element of claim 7; wherein the

number of the discontinuous surfaces which are formed in a stepped shape along a direction of the optical axis and composes the optical path difference giving structure, is 2 or 3.

15. The optical element of claim 1; wherein the first wavelength λ_1 satisfies

$$370\text{nm} \leq \lambda_1 \leq 430\text{nm}, \text{ and}$$

the second wavelength λ_2 satisfies

$$620\text{nm} \leq \lambda_2 \leq 680\text{nm}.$$

16. The optical element of claim 1; wherein the structure having the diffracting function sets a sum of a diffraction efficiency of the L-th order diffracted light of the light beam having the first wavelength λ_1 and a diffraction efficiency of the M-th order diffracted light of the light beam having the second wavelength λ_2 to 170% or less, and the optical path difference giving structure heightens the sum of the diffraction efficiency of the L-th order diffracted light of the light beam having the first wavelength λ_1 and the diffraction efficiency of the M-th order diffracted light of the light beam having the second wavelength λ_2 by 10% or more.

17. An objective optical element which is the optical element of claim 1;

wherein the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are respectively incident on the optical surface as a diverging light beam, and the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are converged on a prescribed optical information recording medium in a condition that spherical aberration and/or wave front aberration are corrected.

18. The objective optical element of claim 17; wherein a magnification m satisfies a formula:

$$-0.295 \leq m \leq -0.049.$$

19. The objective optical element of claim 17; wherein a curvature radius R_1 of a paraxial region of an optical surface on a light source side and a curvature radius R_2 of a paraxial region of an optical surface on the optical information recording medium side satisfies a formula:

$$-3.2 < R_2/R_1 < -1.9.$$

20. The optical element of claim 1; wherein the first wavelength λ_1 and the second wavelength λ_2 are a use reference wavelength.

21. An objective optical element which is the

optical element of claim 20;

wherein the optical path difference giving structure gives an optical path difference to the diffracted light so that a -N-th order diffracted light of the light beam having the use reference wavelength λ_1 has a maximum diffraction efficiency and so that a (-N+1)-th order diffracted light of the light beam having the use reference wavelength λ_2 or a (-N-1)-th order diffracted light of the light beam having the use reference wavelength λ_2 has a maximum diffraction efficiency.

22. The objective optical element of claim 21;
wherein the optical surface of the diffracting ring-shaped zone has a structure substantially inclined with respect to the optical surface formed in a prescribed aspherical shape, the structure substantially inclined having a discontinuous surface formed in a serrate shape, and

the optical path difference giving structure has a discontinuous surface formed in a stepped shape along the direction of the optical axis.

23. The objective optical element of claim 21;
wherein the optical surface of the diffracting ring-shaped zone has a structure substantially inclined with respect to the optical surface formed in a prescribed aspherical shape, the structure substantially inclined having a discontinuous

surface formed in a stepped shape along the direction of the optical axis, and

the optical path difference giving structure has a discontinuous surface formed in a stepped shape along the direction of the optical axis.

24. The objective optical element of claim 21; wherein the optical surface formed in the prescribed aspherical shape is partitioned into a central region arranged around the optical axis and formed in an approximately circular shape, and a peripheral region surrounding a periphery of the central region,

the diffracting ring-shaped zones are arranged in the central region, and

a diffracting ring-shaped zone formed in the serrate shape is arranged in the peripheral region.

25. The objective optical element of claim 21; wherein the optical surface formed in the prescribed aspherical shape is partitioned into a central region arranged around the optical axis and formed in an approximately circular shape, and a peripheral region surrounding a periphery of the central region,

the diffracting ring-shaped zones are arranged in the central region, and

the optical path difference giving structure is

arranged in the peripheral region.

26. The objective optical element of claim 21;
wherein the optical surface formed in the prescribed
aspherical shape is partitioned into a central region
arranged around the optical axis and formed in an
approximately circular shape, and a peripheral region
surrounding a periphery of the central region,

the diffracting ring-shaped zones are arranged in the
central region, and

a refractive structure for reflecting the light beam
is arranged in the peripheral region.

27. The objective optical element of claim 21;
wherein the number of diffracting ring-shaped zones is from
3 to 20.

28. The objective optical element of claim 21;
wherein the optical path difference giving structure gives
an optical path difference equal to an integral multiple of
the use reference wavelength λ_2 to the light beam having
the use reference wavelength λ_2 .

29. The objective optical element of claim 21;
wherein $L = M$ is satisfied.

30. The objective optical element of claim 21;
wherein $L = N$ is satisfied.

31. The objective optical element of claim 21;
wherein $M = N$ is satisfied.

32. The objective optical element of claim 21;
wherein $L = M = N$ is satisfied.

33. The objective optical element of claim 21;
wherein the light beam having the use reference wavelength
 λ_1 and the light beam having the use reference wavelength
 λ_2 are respectively incident on the optical surface as a
diverging light beam, and the light beam having the use
reference wavelength λ_1 and the light beam having the use
reference wavelength λ_2 are converged on a prescribed
optical information recording medium in a condition that
spherical aberration and/or wave front aberration are
corrected.

34. The objective optical element of claim 21;
wherein a magnification m satisfies a formula;
 $-0.295 \leq m \leq -0.049$.

35. The objective optical element of claim 21;
wherein a curvature radius R_1 of a paraxial region of an

optical surface on a light source side and a curvature radius R2 of a paraxial region of an optical surface on the optical information recording medium side satisfies a formula:

$$-3.2 < R_2/R_1 < -1.9.$$

36. An optical pickup device for reproducing and/or recording information for a first optical information recording medium having a protect substrate thickness t_1 by using a light beam having a first wavelength λ_1 emitted from a first light source, and for reproducing and/or recording information for a second optical information recording medium having a protect substrate thickness t_2 ($t_2 \geq t_1$) by using a light beam having a second wavelength λ_2 ($\lambda_2 > \lambda_1$) emitted from a second light source, the optical pickup device comprising:

a plurality of optical elements;

wherein at least one of the optical elements comprises a diffractive structure having a plurality of diffracting ring-shaped zones arranged around an optical axis on at least an optical surface; and

an optical path difference giving structure arranged on an optical surface of at least one of the plurality of diffracting ring-shaped zones, for giving a prescribed optical path difference to a prescribed light beam passing through the diffracting ring-shaped zone,

wherein the optical surface of the diffractive structure is a structure having a diffracting function for setting L-th ($L \neq 0$) order diffracted light of the light beam having the first wavelength λ_1 to a maximum diffraction efficiency and for setting M-th ($M \neq 0$) order diffracted light of the light beam having the second wavelength λ_2 to a maximum diffraction efficiency in case of an assumption of no existence of the optical path difference giving structure.

37. The optical pickup device of claim 36; wherein as compared with the assumption of no existence of the optical path difference giving structure, the optical path difference giving structure lowers an absolute value of an optical phase difference between the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 by changing a phase of at least one of the L-th order diffracted light of the light beam having the first wavelength λ_1 and the M-th order diffracted light of the light beam having the second wavelength λ_2 , the L-th order diffracted light and the M-th order diffracted light being caused by the structure having the diffracting function.

38. The optical pickup device of claim 37; wherein

one of the optical elements is an objective optical element, and the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are respectively incident on the objective optical element as a diverging light beam, and

the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are converged on a prescribed optical information recording medium in a condition that spherical aberration and/or wave front aberration are corrected.

39. The optical pickup device of claim 37; wherein a magnification m satisfies a formula:

$$-0.295 \leq m \leq -0.049.$$

40 The optical pickup device of claim 37; wherein information is reproduced and/or recorded for a third optical information recording medium having a protect substrate thickness t_3 ($t_3 > t_2$) by using a light beam having a third wavelength λ_3 ($\lambda_3 > \lambda_2$) emitted from a third light source.

41. The optical pickup device of claim 36; wherein the first wavelength λ_1 and the second wavelength λ_2 are a use reference wavelength.

42. The optical pickup device of claim 41; wherein the optical path difference giving structure gives an optical path difference to the diffracted light so that a -N-th order diffracted light of the light beam having the use reference wavelength λ_1 has a maximum diffraction efficiency and so that a $(-N+1)$ -th order diffracted light of the light beam having the use reference wavelength λ_2 or a $(-N-1)$ -th order diffracted light of the light beam having the use reference wavelength λ_2 has a maximum diffraction efficiency.

43. The optical pickup device of claim 42; wherein the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are respectively incident on the objective optical element as a diverging light beam, and the light beam having the first wavelength λ_1 and the light beam having the second wavelength λ_2 are converged on a prescribed optical information recording medium in a condition that spherical aberration and/or wave front aberration are corrected.

44. The optical pickup device of claim 42; wherein a magnification m satisfies a formula:

$$-0.295 \leq m \leq -0.049.$$

45. The optical pickup device of claim 42; wherein

information is reproduced and/or recorded for a third optical information recording medium having a protect substrate thickness t_3 ($t_3 > t_2$) by using a light beam having a third wavelength λ_3 ($\lambda_3 > \lambda_2$) emitted from a third light source.